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HIGH STRENGTH AND HIGH DUCTILITY MAGNESIUM ALLOY AND ITS PREPARATION METHOD

TECHNICAL FIELD OF THE INVENTION

The invention related to a magnesium alloy and its preparation method. An object of the invention is to create a casting magnesium-based alloy having high strength and high ductility at low cost. The present invention was not only applicable for permanent casting process, but also shall be applicable for other processes such as sand casting, die casting, and squeeze casting.

BACKGROUND OF THE INVENTION

As a lightweight metallic material, magnesium alloy has many advantages, such as excellent specific strength, superior machinability and castability, good damping capacity, good dimensional stability, and ability of electromagnetic shielding. Due to these advantages, magnesium alloy parts have already extensively applied in many industrial branches, including manufactures of automobiles, 3C products (Computer, Communication, Consumer Electrics), and military weapons, etc. In recent years, because of the ever-pressing weight reduction demand, magnesium alloy became very attractive again for transportation applications, and the demands of magnesium alloys increased steadily and rapidly.

However, the low strength and/or ductility of magnesium alloys, relative to aluminum alloys, have greatly restricted their applications, such as application on the wheels of lightweight vehicles, where high strength and high ductility are both required. Table 1 gives the tensile properties of some typical commercial casting magnesium alloys as references.

Table 1 Properties of typical casting magnesium alloys

Alloys	Composition (wt%)					Tensile properties		
	Al	Zn	Mn	Zr	Others	σ_b(MPa)	$\sigma_{0.2}$(MPa)	δ_5(%)
Die Casting								
AM60	6.0	-	0.3	-	-	220	115	8
AZ91	9.0	0.7	0.3	-	-	230	150	3
Casting								
ZE63	-	5.8	-	0.7	2.6RE	300	190	10

Referring to Table 1, die casting magnesium AZ91, which is the most widely used alloy, have a high strength, but its relatively low ductility restrains its applications; On the other hand, die casting magnesium alloy AM60 has high ductility, but its medium strength also limits its applications; Although there are a few Mg-RE casting magnesium alloys, such as ZE63, bear high strength and

high ductility at the same time, but the high cost and complicated heat treatment procedure make them difficult to apply. Since improving the strength and ductility became pivotal to widen the application of magnesium alloy, developing a high strength and high ductility magnesium alloy at low cost became more and more important nowadays.

Many attempts to improve the tensile properties of magnesium alloys have been done, however, most of them are focused on the elevated-temperature tensile properties, and the room-temperature tensile properties of these attempts are limited. For examples, European patent 0879898A1 disclosed a magnesium alloy having superior elevated-temperature properties and die castability, but the disclosed alloys have relatively low room-temperature strength (UTS < 230 MPa) and ductility (Elongation < 5%); US Patent 20030084968A1 disclosed a high strength creep resistant magnesium alloy, but these alloys also have relatively low room-temperature ductility (Elongation < 5%); US Patent 6139651 disclosed a magnesium alloy for high temperature applications, but the combination of high strength and high ductility of the alloys at room-temperature isn't desirable. Although a few attempts obtained some promising alloy that has a good combination of high strength and high ductility at room temperature, such as US patent 20010055539A1, more new alloys that have much better combination of high strength and high ductility at room temperature need to develop still further.

In recent years, the effects of trace element addition (such as rare earths, beryllium, bismuth, strontium, antimony, etc.) on magnesium alloys have been studied, but most of them also concentrated on improving creep-resistant properties of commercial magnesium alloys. For examples, Chinese patent CN1401804 disclosed a low cost heat-resistant magnesium alloy, which contains Al (2-10 wt.%), Zn (0.2-2 wt.%), Mn (0.1-0.6 wt.%), Bi (0.1-2 wt.%), Sb (0.1-1.5 wt.%) and Mg (the rest). European patent 1241276 also disclosed a creep-resistant magnesium alloy, which is made from 1.5 to 4.0 wt% of Al, 0.5 to 1.8 wt % of Si, 0.05 to 0.6 wt % of RE, 0.005 to 1.5 wt % of Sr or Sb, and balanced Mg; Chinese patent CN1341767 disclosed a multicomponent heat-resistant magnesium alloy for car and its preparation, which includes Al (5-7 wt%), Zn (0.5-1.0 wt%), Si (0.6-1.5 wt%), Sb (0.4-0.7 wt%), RE (0.1-0.3 wt%), Be (0.002% wt%), and balanced Mg.

On the basis of comprehensive analyses of literature, we noted that with the help of trace element addition and proper heat treatments there might be potentials in medium-high aluminum, medium-high zinc die castable Mg-Al-Zn zone for developing low cost, high strength, and high ductility magnesium alloys. As a result, we found some species, which will be discussed in detail infra, that have such qualifications.

SUMMARY OF THE INVENTION

It is an object of this invention to provide magnesium alloys with good combination of high strength and high ductility by small amount of proper alloying element addition and proper heat treatments.

It is another object of this invention to provide alloys that are not only applicable for permanent casting, but also are applicable for other casting processes, such as sand casting, die casting, squeeze casting, etc.

It is a further object of this invention to provide alloys that not only have superior room temperature mechanical properties, but some of them also have good high temperature mechanical properties.

It is a still further object of this invention to provide alloys that have relatively low cost besides the aforesaid properties.

The most important findings of the present invention are: medium-high aluminum and medium-high zinc contents give the basis of combination of high strengthen and high ductility; The trace element additions and appropriate heat treatments further enhance the alloy to its optimal condition.

The present invention contains 3~9 wt% aluminum, 3.5~9 wt% zinc, 0.15~1 wt% of manganese, 0.01~2 wt% of antimony, and balanced magnesium. The alloy may further comprise 0~2 wt.% of one element selected from the group consisting of mischmetal, calcium, and silicon.

The mechanism to enhance strength and ductility in the present invention is as follows: 1) The solid solution strengthening mechanism. 2) The secondary precipitation strengthening mechanism: with the increase of zinc content, the amount of $Mg_{17}Al_{12}$ phase decrease and Mg-Al-Zn ternary phase and/or binary Mg-Zn phase are becoming important strengthening phases. At the same time, Mn, Sb, and other trace element additions produce Al-Mn, Mg_3Sb_2, and other strengthening phases or particles. 3) Some element addition (such as antimony) can reduce the primary grain size and refine the secondary precipitating phases that continuously distributed along grain boundaries, and so to improve the strength, ductility, and castability of the alloys. 4) Appropriate heat treatments would further enhance the mechanical properties by adjusting the amount and shape of the secondary precipitating phases.

<u>Aluminum (Al): 3~9 wt%</u>

Aluminum is a very effective alloying element in improving strength and hardness of magnesium alloy at room temperature. Aluminum also widens the freezing range and makes the casting process of magnesium alloy easier. In order to obtain the strengthening effect, a minimum of 3 wt% of aluminum shall be added in the alloy according to the present invention. However, excess aluminum would be harmful to the ductility. Accordingly, a preferred upper limit of the aluminum range is set at 9 wt%.

<u>Zinc (Zn): 3.5~9 wt%</u>

Zinc is another significant alloying element in magnesium besides aluminum. Zinc is used in combination with aluminum to improve room-temperature strength and castability at the present invention. However, it has been well

known that inappropriate aluminum/zinc ratio would increase hot cracking susceptibility and worsen die castability. By choosing proper aluminum and zinc contents in the die castable area according to die castability of Mg-Al-Zn (referring to Figure 1), and with the help of small amount of certain element addition (such as antimony), the castability could be improved and hot cracking susceptibility would decrease remarkably. Accordingly, a minimum of 3.5 wt% of zinc shall be added in the present invention. On the other hand, too much zinc would cause ductility reduction. And so, a preferred upper limit of the zinc range is set at 9 wt%.

Manganese (Mn): 0.15~1 wt%

Manganese was added in the form of Al-Mn master alloy. Although manganese does not have much effect on tensile strength, it can increase yield strength slightly by the Al-Mn particles existed in primary grains. The most important function of manganese is to improve the corrosion resistance by transforming heavy-metal elements (such as iron, nickel, etc.) into relatively harmless intermetallic compounds, which precipitated to the bottom of crucible and were eliminated from the melt. The amount of manganese is limited by its relatively low solid solubility in magnesium, and a preferred manganese content range is set between 0.15 and 1 wt% at the present invention.

Antimony (Sb): 0.01~2 wt%

Antimony was added in the form of powder wrapped with aluminum foil or in the form of lumps. Small amount of antimony addition would refine the primary grains and secondary precipitates, hence to improve the mechanical properties and reduce the hot tearing susceptibility. But coarsened Mg_3Sb_2 particles would decrease the tensile properties as Sb content exceed 2 wt%. So, a preferred antimony content range is set from 0.01 to 2 wt% at the present invention.

Other element: 0~2 wt%

The present invention may further comprise 0~2 wt% of one element selected from the group consisting of mischmetal, calcium, and silicon.

The Mischmetal used at the present invention was provided by BaoTou HuaMei Rare Earths High-Tech Limited Company, Inner Mongolia Province, China. Mischmetal is a natural mixture of the rare earths containing about 50% cerium, the remainder being principally lanthanum and neodymium. Small amount of mischmetal addition would increase the hardness and the elevated-temperature strength of magnesium alloys. However, excessive rare earths addition would not only increase the cost of alloy, but also give birth to coarsened precipitated particles and result in decrease of mechanical properties and castability. A preferred rare earths content range is set between 0 to 2 wt%; more preferably the upper content range shall be 0~1 wt%.

Calcium addition would protect the melting from combustion and improve elevated temperature strength and creep resistance. However, calcium addition would deteriorate the castability and increase hot cracking.

Silicon addition is also effective to enhance elevated temperature strength and creep resistance. But excessive silicon would produce coarsened Mg_2Si particles and decrease the mechanical properties.

The smelting and casting procedures at the present invention could be divided into the following steps:

1) Set the temperature of the crucible to 700~750℃ and start heating. Preheat the raw materials in an oven at 140~200℃, and dry the covering flux at the same time. The flux can use the common casting magnesium alloy and quantity of the flux is 0.6~4 wt% of total weight of the alloy. Preheat the casting mold in another oven at 200~400℃;
2) When the temperature of the crucible rise up to 280~320℃, introduce the CO_2 gas into the crucible to replace the air, put 30%~50% of the preheated covering flux into the bottom of the crucible, then put the preheated pure magnesium ingot into the crucible;
3) After the melting of the pure magnesium ingot, while the temperature of the melting rise up to 700~750℃, introduce other preheated raw materials into the melting in turn from high melting point one to low melting point one, and then stir the melting for 8~10 minutes; In this step, put some of the residual preheated covering flux onto the top of the melting to prevent combustion of the melting;
4) After stabilizing the melting at 700~750℃ for 4~6 minutes, remove the scum from the top of the melting; In this step, introduce the mixed protective gases, which has composition of 99~99.5vol% air or CO_2 plus 0.5~1vol%SF_6, to prevent the melting from combustion;
5) After scumming, while maintaining the temperature of the melting at 700~750℃, cast the melting into the preheated mold under the protection of mixture protective gases, which has composition of 99~99.5vol% air or CO_2 plus 0.5~1vol%SF_6.

Heat treatments influence the mechanical properties to a great extent in the present invention. The heat treatments adopted herein are classified into three types: T4 temper (solution heat treatment), T5 temper (artificial ageing without solution heat treatment), and T6 temper (artificial ageing after solution heat treatment).

T4 temper shall be handled under protective gases (such as argon, or 99~99.5vol% air (or CO_2) + 0.5~1vol%SF_6). The temperature of T4 temper was 340~400℃ and was intimately relevant to the content of zinc. As a rule, the temperature of T4 temper shall be 10~20℃ below the solidus temperature. The temperature of solidus of Mg-Al-Zn ternary system can refer to Figure 2. Some other elements (such as antimony) would influence the solidus temperature slightly and a more precise solidus temperature can be acquired from the differential thermal analysis (DTA) of the specific alloy. As for the heating duration for T4 temper, it shall be 8~24 hours.

The temperature of T5 temper shall be 70~200℃, and the heating duration shall be 8~24 hours. As for T6 temper, it can be think of as combination of T4

and T5 tempers. To be specific, firstly do the T4 temper, then do the T5 temper.

By adjusting the amounts and distribution of the secondary precipitation, heat treatments greatly influences the mechanical properties. As a rule, T4 temper would enhance ductility and cause maximum toughness but would decrease yield tensile strength somewhat, for most of the precipitates redissolve into primary grains. T5 temper could relieve residual stress and improve mechanical properties to some extent. By redistribute the amount shape of secondary precipitates, T6 temper gives maximum hardness and yield tensile strength but with some sacrifice of ductility.

The room temperature mechanical properties of the T6 tempered (artificial ageing after solution heat treatment) typical alloy according to the present invention are as following: Ultimate Tensile Strength of not less than 270Mpa, Yield Tensile Strength of not less than 140Mpa, Elongation of not less than 6%, Brinell hardness of not less than 70, Impact Energy of not less than 12J.

The advantages of the present inventions can be summarized as following:

1) High strength and high toughness at room temperature. Especially meet with the demands in lightweight, high strength, and high ductility structural applications, such as car wheels.
2) Alloys according to the present invention not only have superior room temperature mechanical properties, but some of them also have good high temperature mechanical properties.
3) High performance at low cost. The alloying elements are easily attainable. The cost of the production is low, so it is suitable for mass manufacture.
4) Melting and casting processes are easily controlled. No by-product due to little unwanted reactions between alloying elements and crucible wall or flux materials.
5) Suitable for most of the casting processes, such as permanent casting, sand casting, die casting, squeeze casting.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph showing the die castability of Mg-Al-Zn and location of the sample alloys.

Figure 2 is a graph showing Mg-Al-Zn ternary phase diagram (solidus surface) and location of the sample alloys.

Figure 3 is a graph showing differential thermal analysis of Example-1 alloy.

Figure 4 is the microstructure of as-cast Example-1 alloy.

Figure 5 is an EDAX picture showing the distribution of Mg_3Sb_2 particles in T4 tempered Example-1 alloy. The arrows indicate the distribution of Mg_3Sb_2 particles.

Figure 6 is the microstructure of T4 tempered Example-1 alloy.

Figure 7 is the microstructure of T6 tempered Example-1 alloy.

Figure 8 is a graph showing comparison of the room temperature tensile properties of three alloys (AZ91, AM60, Example-1) in their as cast condition.

Figure 9 is a graph showing comparison of the room temperature tensile properties of three alloys (AZ91, AM60, Example-1) in their T6 tempered condition.

Figure 10 is a graph showing comparison of the room temperature tensile properties of four alloys (Example-1, Example-2, Example-3, AZ91) in their T6 tempered condition.

Figure 11 is a graph showing comparison of the high temperature (150℃) tensile properties of four alloys (Example-1, Example-2, Example-3, AZ91) in their T6 tempered condition.

Figure 12 is a graph showing comparison of the room temperature tensile properties of three alloys (Example-4, Example-5, AZ91) in their T6 tempered condition.

DETAILED DESCRIPTION OF THE INVENTION

Now, the high strength and high ductility alloy according to the present invention will be described in more detail, with reference of example alloys.

Example-1

I) The compositions

Three magnesium alloys were prepared in a mild steel crucible using commercial high-purity raw materials. Among them, commercial alloy AZ91 and AM60 acted as reference alloys. Chemical composition analyses of the three alloys were performed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) and the chemical compositions are listed in Table 2.

Table 2. The chemical composition of three alloys (wt %)

Alloys	Al	Zn	Mn	Sb	Mg
AZ91	9.00	1.03	0.29	-	Bal.
AM60	5.92	-	0.28	-	Bal.
Example-1	5.88	3.89	0.30	0.51	Bal.

II) The smelting and casting

The smelting was carried out in a resistance furnace and a crucible having a capacity of 15 kg. The crucible and the casting mold were made of mild steel. Taking Example-1 alloy as an example, the smelting and casting processes are described in detail as following:

1) Set the temperature of the crucible to 720℃ and start heating. Preheat the raw material (pure magnesium, pure aluminum, Al-Mn master alloy, pure antimony, pure Zinc) in an oven at 160℃; and dry the RJ-2 covering flux (2 wt% of total weight of the preparing alloy) at the same time. The RJ-2 covering flux, which was designated ZS-MF1 by its manufacture, was provided by LanDe High-Tech Limited Company, Sichuan Province, China. Preheat the casting mold in another oven at 300℃.

2) When the temperature of the crucible rise up to 300℃, introduce the CO_2 gas into the crucible to replace the air, put half of the preheated RJ-2 flux into the bottom of the crucible, then put the preheated pure magnesium into the crucible.
3) After stabilizing the melting at 720℃, put the other preheated raw materials (pure aluminum, Al-Mn master alloy, pure antimony, pure Zinc) into the melting in turn, then stir the melting for 8~10 minutes. In this step, put some of the preheated RJ-2 flux onto the top of the melting to stop combustion.
4) Stabilize the melting at 720℃, then keep the melting still for 4~6 minutes, and then pull out the scruff; In this step, introduce the mixed protective gases (99~99.5vol% air (or CO_2) + 0.5~1vol%SF_6) to prevent or stop the combustion of the melting.
5) After skimming the scruff, while keeping the temperature of the melting at 720℃, cast the melting into the preheated mold under the protection of mixed protective gases (99~99.5vol% air (or CO_2) + 0.5~1vol%SF_6).

The smelting and casting process of AZ91 or AM60 was similar to the Example-1, with the exception of different quantity of ingredients.

III) The heat treatments

The heat treatments of the three alloys can be divided into three types: T4 temper (solution), T5 temper (ageing), and T6 temper (solution + ageing).

a) T4 temper: The temperature of T4 temper could be deduced from its DTA data. For example (Referring to Figure 3), there are two turning points (377 ℃, 354℃) near the solidus on the DTA curve of the Example-1. According to experiments, the T4 temper temperature of Example-1 should not exceed 370℃. The T4 temper temperature of Example-1 was 370℃ and the heating duration was 12 hours. As for AZ91 and AM60, the T4 temper temperature were 410℃ and the heating duration were 16~24 hours. The after heat-treated samples were cooled in air at the end of T4 temper.
b) T5 temper: All three alloys can have the same T5 heat treatment. The temperature of T5 temper was 180℃ and the duration was 16 hours. The after heat-treated samples were cooled in air at the end of T5 temper.
c) T6 temper: T6 temper can be think of as combination of T4 and T5 tempers. Each alloy went through its solution heat treatment and artificial aging in turn under its suitable temperature and duration aforementioned.

IV) The microstructural evolutions

The specimens for microstructural observation were prepared by standard wet grinding with #1000 SiC abrasive papers and mechanically polished with oil-based diamond suspensions. Then the polished specimens were etched with a 2% solution of nitric acid in ethanol. The microstructural observations were conducted by a Philips XL30 ESEM-FEG/EDAX scanning electron microscope (SEM) and energy dispersive spectroscope (EDS).

Compared to the alloy without antimony addition, Example-1 has a much finer primary grains and much finer secondary precipitation (Referring to Figure 4). This mechanism can be assumed like this: small amount of antimony addition would result in Mg_3Sb_2 particles, which has a melting point of 1228℃. These Mg_3Sb_2 particles would form earlier in the cooling melt, and some of the Mg_3Sb_2 particles could be the heterogeneous nuclei of the primary phase to reduce the grain size of the primary phase; Other Mg_3Sb_2 particles would exist in the liquid ahead of the growing interface and could interact with the precipitation of secondary phases and make a more dispersive secondary phase distribution. In the SEM/EDAX observations, Mg_3Sb_2 particles are discovered both in the primary grains and at the grain boundaries (Referring to Figure 5).

The evolutions of microstructures of Example-1 causing by different heat treatments were exhibited in Figure 6 and Figure 7. From Figure 6, it can be seen that most of the secondary precipitates redissolve into primary phase by T4 temper, and the residual particles are mostly particles with high melting point (such as Mg_3Sb_2 and/or Al-Mn particles). T6 temper makes the solutes precipitate again from primary grains as more dispersive secondary phases, which redistributed along grain boundaries and in the grains as well (Referring to Figure 7).

Ⅴ) The mechanical properties

The samples of room temperature tensile property were prepared referring to Chinese GB 6397-86. The gauge dimension of the samples was 30×6×3 mm. The surfaces of the samples were grinded with #1000 wet SiC abrasive papers. The stress rate of the tensile tests is $1.11\times10^{-3}S^{-1}$.

The gauge dimension of the high temperature (150℃) tensile property samples was 27×5×3 mm. The surfaces of the samples were grinded with #1000 wet SiC abrasive papers. The stress rate of the tensile tests is $5.55\times10^{-4}S^{-1}$.

The samples of Brinell hardness test were prepared referring to Chinese GB 231-84. The gauge dimension of the Brinell hardness test samples was 15×15×5 mm.

The samples without indentation of impact energy were prepared referring to Chinese GB/T 229-1994. The gauge dimension of the samples was 10×10×55 mm.

Figure 8 gives the tensile property comparison of as cast alloys including AZ91 (F), AM60 (F) and Example-1 (F). Figure 9 gives the tensile property comparison of T6 heat-treated alloys including AZ91 (T6), AM60 (T6) and Example-1 (T6).

Table 3. The room temperature mechanical properties of Example-1

Heat Treatment	YTS (MPa)	UTS (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J)

As cast	216	106	10	60	19
T4 temper	250	101	12	59	30
T5 temper	230	128	7	65	12
T6 temper	285	137	8.5	68	18

It can be seen from Table 3 that T4 temper enhances ductility of the as-cast alloy. T5 temper improves mechanical properties to some extent. T6 temper attains maximum yield strength and tensile strength but with some sacrifice of ductility compared with T4 temper.

The comparison of room temperature tensile property between Example-1 and AZ91 was illustrated in Figure 10, and the comparison of 150℃ tensile property between Example-1 and AZ91 was given in Figure 11。 It can be seen that although the comprehensive room temperature tensile property of Example-1 is superior to that of AZ91, but the high temperature tensile property is somewhat below that of AZ91.

Example-2

Ⅰ) The compositions

The chemical composition of Example-2 is listed in Table 4.

Table 4. Alloys Composition of Example-2 (wt %)

Alloys	Al	Zn	Mn	Sb	Mg
Example-2	6.16	5.08	0.31	0.48	Bal.

Ⅱ) The smelting and casting

Referring to the smelting and casting of Example-1. The difference mainly lies in the zinc content of the two alloys.

Ⅲ) The heat treatments

Referring to the heat treatments of Example-1. The difference mainly lies in that the temperature of T4 temper was 360℃ according to the DTA analysis of Example-2, and the heating duration was 12 hours. The artificial ageing temperature of T5 temper was 180℃ and the duration was 16 hours.

Ⅳ) The mechanical properties

Referring to the tests of various mechanical properties of Example-1.

Table 5. The room temperature mechanical properties of Example-2

Heat Treatment	YTS (MPa)	UTS (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J)
As cast	110	210	8	63	15
T6 temper	145	250	6	74	12

The comparison of 150℃ tensile property between Example-2 and AZ91 was given in Figure 11. From Table 5 and Figure 11, it can be seen that both of room temperature and high temperature mechanical properties of Example-2 are superior to that of AZ91.

Example-3

Ⅰ) The compositions

The chemical composition of Example-3 is listed in Table 6.

Table 6. Alloys Composition of Example-3 (wt %)

Alloys	Al	Zn	Mn	Sb	Mg
Example-3	5.89	6.74	0.35	0.53	Bal.

Ⅱ) The smelting and casting

Referring to the smelting and casting of Example-1. The difference mainly lies in the zinc content of the two alloys.

Ⅲ) The heat treatments

Referring to the heat treatments of Example-1. The difference mainly lies in that the temperature of T4 temper was 350℃ according to the DTA analysis of Example-3, and the heating duration was 12 hours. The artificial ageing temperature of T5 temper was 180℃ and the duration was 16 hours.

Ⅳ) The mechanical properties

Referring to the tests of various mechanical properties of Example-1.

Table 7. The room temperature mechanical properties of Example-3

Heat Treatment	YTS (MPa)	UTS (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J)
As cast	115	202	6.5	67	13
T6 temper	153	260	5	77	9

The comparison of 150℃ tensile property between Example-3 and AZ91 was given in Figure 11. From Table 7 and Figure 11, it can be seen that not only the room temperature mechanical property of Example-3 is good enough comparing to that of AZ91, but the 150℃ UTS of Example-3 is superior to that of AZ91 also.

Example-4

Ⅰ) The compositions

The chemical composition of Example-4 is listed in Table 8.

Table 8. Alloys Composition of Example-4 (wt %)

Alloys	Al	Zn	Mn	Sb	MM*	Mg
Example-4	6.00	3.79	0.54	0.50	0.90	Bal.

* MM is the abbreviation of mischmetal.

II) The smelting and casting

Referring to the smelting and casting of Example-1. The difference between them mainly lies in that there is small quantity of mischmetal in Example-4.

Because of the high melting point of mischmetal, when adding raw materials into the melt, mischmetal shall be added first and the temperature of the melt in the crucible shall keep at 750~800℃ at that time.

III) The heat treatments

Referring to the heat treatments of Example-1. The difference between them mainly lies in that the temperature of T4 temper of Example-4 was 370℃ according to its DTA analysis, and the heating duration was 12 hours. The artificial ageing temperature of T5 temper was 180℃ and the duration was 16 hours.

IV) The mechanical properties

Referring to the tests of various mechanical properties of Example-1.

Table 9. The room temperature mechanical properties of Example-4

Heat Treatment	YTS (MPa)	UTS (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J)
As cast	111	230	10	64	19
T6 temper	146	272	8.7	77	13

From Table 9, it can be seen that the comprehensive room temperature mechanical property of Example-4 is superior to that of AZ91. The comparison of 150℃ tensile property between Example-4 and AZ91 was given in Figure 12. The high temperature tensile property of Example-4 is somewhat below that of AZ91, which is demonstrated in Figure 12.

Example-5

I) The compositions

The chemical composition of Example-5 is listed in Table 10.

Table 10. Alloys Composition of Example-5 (wt %)

Alloys	Al	Zn	Mn	Sb	MM*	Mg
Example-5	4.77	5.59	0.42	0.45	0.49	Bal.

* MM is the abbreviation of mischmetal.

II) The smelting and casting

Referring to the smelting and casting of Example-1. Small quantity of mischmetal in Example-4 except for the differences in aluminum, zinc amounts.

Because of the high melting point of mischmetal, when adding raw materials into the melt, mischmetal shall be added first and the temperature of the melt in the crucible shall keep at 750~800℃ at that time.

III) The heat treatments

Referring to the heat treatments of Example-1. The difference between them mainly lies in that the temperature of T4 temper was 350℃ according to the DTA analysis of Example-5, and the heating duration was 12 hours. The temperature of T5 temper was 180℃ and the duration was 16 hours.

IV) The mechanical properties

Referring to the tests of various mechanical properties of Example-1.

Table 11. The room temperature mechanical properties of Example-5

Heat Treatment	YTS (MPa)	UTS (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J)
As cast	115	210	7.4	68	15
T6 temper	156	282	7.0	79	12

The comparison of 150℃ tensile property between Example-5 and AZ91 was given in Figure 12. From Table 11 and Figure 12, it can be seen that not only the comprehensive room temperature tensile property of Example-5 is superior to that of AZ91, but the 150℃ UTS of Example-5 is superior to that of AZ91 also.

Claims

1. A high strength and high ductility magnesium alloy and its preparation method, characterized in that the alloy comprises 3~9 wt.% of aluminum, 3.5~9 wt.% of zinc, 0.15~1 wt.% of manganese, 0.01~2 wt.% of antimony, and balanced magnesium.
2. The high strength and high ductility magnesium alloy according to Claim 1, characterized in that wherein antimony could be commercial purity (99.7%).
3. The high strength and high ductility magnesium alloy according to Claim 1, characterized in that wherein the alloy may further comprise 0~2 wt.% of one element selected from the group consisting of mischmetal, calcium, and silicon.
4. A preparation method of the high strength and high ductility magnesium alloy magnesium alloy according the Claim 1, characterized in that wherein the smelting and casting procedures of the alloy preparation were as following: